California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Transportation System Preservation

Technical Memorandum

Booz·Allen & Hamilton Inc.
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LIST OF EXHIBITS

1. EXECUTIVE SUMMARY

Transportation System Preservation is one of ten outcomes in the performance measurement initiative being led by the California Department of Transportation (Caltrans). The Transportation System Preservation outcome focuses on the condition of the transportation system. This outcome evolved out of the Sustainability outcome. Preservation captures the asset management and preservation concept.

Asset management systems can provide a tool to assess asset condition. They can also evaluate the cost of preserving the transportation system over time, which can be used to help direct funding strategies. Asset management systems are available for most modes of the transportation system and are currently used at the federal, state, regional, and local levels. These systems can be used to develop a modally-blind transportation system preservation indicator that considers "asset condition" and the cost to achieve a desired condition level over time. Both desired system and performance objectives must be defined.

Proof-of-concept testing for this outcome identified several existing preservation measures, such as distressed lane-miles, that describe transportation asset condition. These measures are mode-specific and not directly comparable with each other. The measures, however, can be used for establishing goals and measurable objectives to enhance decision making for preserving modal assets.

The Asset Condition indicator can be supplemented with two modally-blind indicators for planning and cross-asset comparisons. These indicators are the Cost to Achieve Desired Condition and the Preservation Index.

Exhibit 1 presents findings, conclusions, and recommendations from the proof-of-concept testing.

Exhibit 1: Findings, Conclusions and Recommendations for System Preservation

FINDINGS	CONCLUSIONS	RECOMMENDATIONS
• System preservation is useful for monitoring system condition, establishing measurable objectives, and enhancing decision making • Modally-specific asset condition indicators are currently in use • Asset management systems link asset condition with the cost to maintain those assets and are available for pavement, bridges, transit vehicles, railroad track, and airfield pavement • Performance for preservation can be defined in terms of maintaining conditions or improving conditions • Improving conditions may include: – Asset conditions – User costs – Economics • Proof-of-concept testing using the Transit Economics Requirements Model (TERM) for transit assets in California indicated that the cost to maintain conditions can be calculated and expressed over time as an index or in dollars	• Asset management systems can be used to calculate Asset Condition, an indicator of preservation • Asset management systems evaluate asset condition and estimate the cost to preserve capital assets over time • A multi-modal preservation indicator, the Preservation Index, can be developed to supplement the Asset Condition indicator • The Preservation Index may calculate several performance levels, including maintaining conditions, improving conditions, or maintaining user costs	• Continue using mode-specific asset condition indicators for individual assets • Adopt and monitor Asset Condition as an indicator of preservation • Consider conducting additional proof-of-concept testing for additional system indicators using the following two strategies: 1) Cost to Achieve Desired Condition 2) Preservation Index – Consider performance/ condition level as maintaining existing asset conditions – Exclude operating costs

2. SYSTEM PRESERVATION OUTCOME PROOF-OF-CONCEPT TESTING

2.1 Introduction

Transportation System Preservation is one of ten outcomes in the performance measurement initiative being led by Caltrans. This outcome focuses on the condition of the transportation system. Transportation System Preservation and Sustainability were originally one outcome.

During 2000, the Policy Advisory Committee (PAC) recommended splitting the Sustainability into two separate outcomes: Transportation System Preservation and Sustainability. The PAC and System Measures Working Group (SMWG) recognized the need to continue research on the sustainability outcome. This is the subject of a separate task.

The groups suggested that the original Sustainability outcome definition be modified to reflect the preservation focus. The PAC subsequently approved the following definition for Transportation System Preservation:

"Preserving the transportation system while meeting the needs of the present without compromising the needs of future generations"

While it may be difficult to define what future generations will need, it is reasonable to assume that they will need at least the existing transportation system. This suggests that the appropriate indicator should measure progress in preserving the existing system. This requires the ability to monitor system conditions and forecast funding needs for replacement, rehabilitation, and repair so that today's investments provide maximum value and efficiency over time.

After further testing of the preservation indicator and discussion with the SMWG, the following new definition has been adopted for Transportation System Preservation:

"Maintaining the physical assets of the transportation system at a specified or agreed upon level"

This report discusses the development of indicators for the Transportation System Preservation outcome. Based on a review of existing performance measures in use at Caltrans, **Asset Condition** was determined to be an appropriate indicator of preservation. A discussion of Asset Condition is presented in Section 2.2. Two other indicators, the **Cost to Achieve Desired Condition** and the **Preservation Index**, can supplement the Asset Condition indicator by serving as strategies to evaluate infrastructure condition on a system/statewide level. These indicators are discussed in Section 2.4.

2.2 Asset Condition

At the foundation of all preservation activities is the condition of each individual asset. Asset condition is the key to preserving the system. This includes both the capability to measure the condition of each individual asset and to preserve each asset to a predetermined, desired condition level. Asset condition and the associated preservation costs can be measured using tools called asset management systems. These systems will be discussed in Section 2.5. Furthermore, a desired condition level may be defined in several ways, including maintaining conditions, improving conditions, or maintaining user costs, among others. Condition level will be discussed in Section 2.6.

Although asset condition is the unifying theme for preservation activities, it also separates each asset from every other asset. In other words, each asset has a unique condition and means by which condition is measured. Moreover, although each mode has one or more critical assets, if all modes were broken down to their smallest sub-asset, there would be hundreds if not thousands of assets. For example, a traffic signal contains many individual assets, including the lighting and wiring. Based on their deterioration rates, the bulbs may require replacement long before the wiring. Therefore, even if both were installed at the same time, after a certain amount of time, the bulbs may be in poor condition while the wiring remains in good condition.

Because there are an indefinite number of assets in the transportation system, measuring preservation merits the identification of several critical assets. The first step is to identify the four major modes that comprise the system: highways, transit, aviation, and rail. Within each of these modes are a few critical assets, as well as many other sub-assets that allow the system to operate. The critical assets are presented in Exhibit 2.

Exhibit 2: Critical Transportation System Assets

Highways	Transit	Aviation	Rail
▸ Pavements	▸ Guideway Elements	▸ Airport pavement (runways and taxiways)	▸ Guideways
▸ Structures	▸ Stations		▸ Intermodal Facilities
▸ Tunnels	▸ Systems		
▸ Hardware	▸ Vehicles		
▸ Other Assets (vehicles, equipment, real estate, materials, etc.)	▸ Facilities		

As discussed previously, each of the assets presented in Exhibit 2 comprises many smaller sub-assets. Specific outputs are generally used to measure the condition of each critical asset as a whole. For example, the condition of pavement is commonly measured based on the ride quality and structural condition. In comparison, the age of a vehicle is a common measure of asset condition for buses.

Measures of asset condition are widely used by Caltrans as asset-specific performance measures. Asset-specific performance measures are used to evaluate the various projects within the State Highway Operation and Protection Program (SHOPP). The purpose of the SHOPP is to preserve and protect the State highway system. It provides funding for the purpose of rehabilitation or reconstruction of all state highways and bridges. The preservation measures in use have been presented successfully to the California Transportation Commission (CTC). Other measures relating to mobility and reliability (such as those collected in the Highway Congestion Monitoring Program) are consistent with system performance measurement. As shown in Exhibit 3, each program within the SHOPP has different asset-specific and output-related performance measures.

Exhibit 3: SHOPP Performance Measures

Safety	Roadside Preservation	Roadway Preservation	Bridge Preservation	Mobility	Environmental Improvement
• Number of new/upgraded safety improvements • Centerline miles of barriers • Miles of barriers upgraded	• Acres of Highway Planting • Roadside Rest Area deficiencies • Areas covered by sprinklers	• Distressed lane miles of pavement • Lane miles of long-life pavement	• Deficient bridge rails • Number of rehabilitated/ replaced structures • Bridge mitigations and repairs	• STAA truck access criteria • Traffic volumes • Lane miles/number of operational improvements • Number of detectors • Centerline miles with TMS field elements • Number of vehicle hours of delay reduced	• Number of Schools with noise attenuation • Number of locations of hazardous waste mitigation • Number of locations of scour water mitigation

A measure of preservation must consider the asset-specific performance measures already in use. Of particular importance to system preservation are performance measures for roadway, bridge, and roadside preservation. These measures provide an assessment of the current condition of individual bridge and highway assets but are not comparable across modes.

Based on the review of performance measures in use at Caltrans, it is recommended that **Asset Condition** be adopted as the preservation indicator for individual assets, as well as the representative indicator for the major mode categories. For the purposes of the system preservation outcome, the condition of the critical assets will represent the condition of each mode.

2.3 Proof-of-Concept Testing

As discussed in the previous section, Asset Condition is the recommended preservation indicator for individual assets and the representative indicator for major mode categories. However, individual asset condition cannot be aggregated at a statewide/system level. Additional techniques can be used to supplement the asset condition indicator at the system level.

The biggest challenge of presenting a measure of preservation for the entire transportation system is ensuring that the indicator is modally-blind and considers all assets equally. At the level of infrastructure maintenance and improvement planning, each mode may have a different definition of condition. As described in Section 2.2, performance indicators of preservation are already in use at Caltrans, but tend to be asset or mode-specific and are not comparable across modes. These performance measures provide valuable information about Asset Condition, the recommended

indicator for the preservation of individual assets. A system measure of preservation cannot replace these measures at the project planning or program evaluation level. Therefore, the Transportation System Preservation outcome should adopt Asset Condition for the evaluation of individual assets. The Asset Condition indicator can also be used to evaluate preservation for individual modes based on the condition of critical assets.

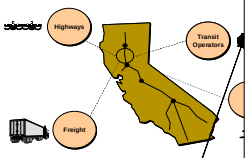
Two modally-blind indicators, the Cost to Achieve Desired Condition and the Preservation Index, may be used to supplement the Asset Condition indicator at a statewide/system level. These are discussed in Section 2.4.

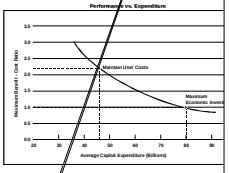
2.4 Techniques for System Preservation

A technique for presenting system preservation needs to have the ability to assess condition for all assets on a greater systemwide level by measuring the condition of individual modes and assets within the system. After system condition is assessed, it must have the ability to calculate the cost of preserving the system into the future. Each type of infrastructure to be measured, the main assets of the multi-modal transportation system, must be identified, including pavements and structures, other highway assets, transit, aviation, and rail. Finally, the technique must be modally blind (i.e., the indicator should not specify what types of assets should be preserved) and applicable to all modes. This means that a comparable condition level needs to be defined across modes.

Two system indicators are proposed to supplement the Asset Condition indicator: the Cost to Achieve Desired Condition and the Preservation Index. The first technique presents the cost in dollars of preserving the system to a desired performance level. The second technique presents this figure as an index to show how it has changed over time. Exhibit 4 presents the steps in calculating the proposed transportation system level preservation indicators.

Exhibit 4: Steps in Calculating Candidate System Level Indicators





associated costs. Using a certain performance level (e.g., maintain conditions), the cost of preserving the system over a designated time horizon (e.g., 20 years) is projected.

The third step requires the projected future costs to be summed to generate an estimate of the cost of preserving the entire system. The indicator should sum future preservation investments over an appropriate time horizon, such as twenty years (the standard time horizon for asset management systems). This time horizon should be consistent across modes. Certain assets may need to be replaced multiple times during the chosen time horizon whereas another asset may not be replaced at all. For example, the design life of pavement may be 30 years compared to an expected life of 12 years for buses. Asset management systems are able to take varying deterioration rates into account through the use of decay curves. Summing costs over time reduces variability due to the timing of maintenance and rehabilitation; cost variability tends to decrease with larger time horizons. The sum of the cost of preserving each asset equals the total cost of preserving the entire transportation system. This is the Cost to Achieve Desired Condition.

In the fourth step, the total cost of preserving the transportation as calculated in the previous step is expressed as a Preservation Index. Calculating the indicator each year and expressing it as an index shows how the cost to preserve the system has changed over time. The index is based on the first year the indicator is calculated. Year One would serve as the base year for the indicator. In Year Two, the indicator would be calculated by dropping the first year and extending the horizon one year into the future. The index is calculated as the Year Two total divided by the Year One total. An index provides insight into the difference required to preserve the system. For example, if Year One is considered 100 and the figure generated in Year Two is 103, then it will cost three percent more to preserve the system. As the index is calculated each year (or every two years), it must remain consistent in a chosen performance level, system definition, and constant dollars.

2.4.1 Testing for California's Transit Assets

Booz Allen conducted proof-of-concept testing for both of the candidate system preservation indicators for California transit assets. The Transit Economic Requirements Model (TERM) was used to calculate asset condition, using data maintained at the federal level. "Maintaining conditions" was selected as the desired performance level.

In the second step, the future costs of maintaining conditions for each asset category were projected over a twenty-year period, as presented in Exhibit 5.

Exhibit 5: Projected Future Costs

ILLUSTRATIVE

Asset Category	1998-2002	2003-2007	2008-2012	2013-2017
Guideway Elements	$10.6	$10.6	$686.4	$41.2
Facilities	$1,937.6	$1,011.0	$1,242.8	$1,761.7
Systems	$50.2	$97.9	$395.3	$405.1
Stations	$19.7	$35.8	$31.5	$66.3
Vehicles	$6,978.1	$7,630.0	$7,715.1	$7,412.8
Total	$8,996.2	$8,785.3	$10,071.1	$9,687.1

Note: Costs are illustrative since TERM was not allowed to converge to its final estimates

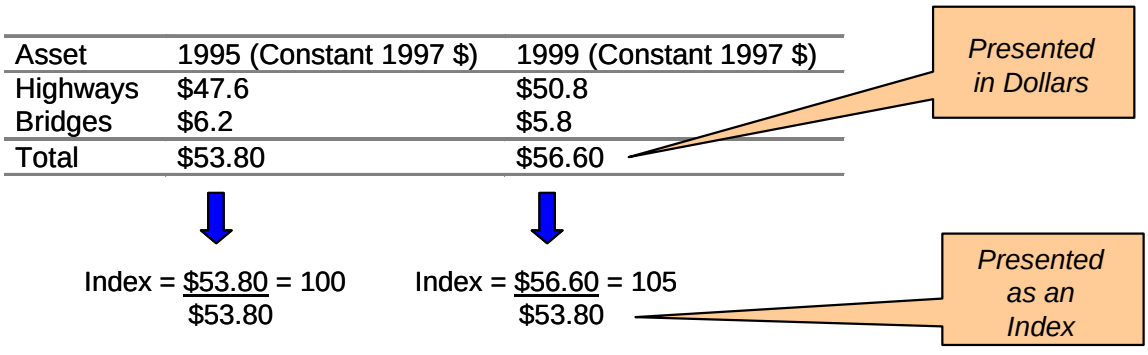
In the next step, the total future costs were summed. This total is the Cost to Achieve Desired Condition, defined as maintaining conditions in this case. Exhibit 6 presents the results.

Exhibit 6: Cost to Maintain Conditions

Asset Category	Constant $	Present Value
Guideway Elements	$750.9	$303.5
Facilities	$6,095.5	$3,300.9
Systems	$1,062.6	$489.0
Stations	$176.5	$91.6
Vehicles	$31,742.6	$17,459.1
Total	$39,828.1	$21,644.1

In the final step, the cost to maintain conditions was expressed as an index. Due to a lack of data availability for transit assets, highway and bridge data from the Condition and Performance Report were used for this step. Exhibit 7 presents the results.

Exhibit 7: Preservation Index



As a result of proof-of-concept testing, Booz Allen concluded that the candidate indicators are able to provide a multi-modal measure of condition of the transportation system. These indicators can supplement the Asset Condition indicator.

2.4.2 Technical Considerations

The candidate system preservation techniques have a role model in a federal application of a preservation indicator. The US Department of Transportation has developed an indicator of system preservation for the Nation's transportation system, presented in the "Status of the Nation's Highways, Bridges and Transit: Condition and Performance" report.[1] The Condition and Performance report provides investment benchmarks to aid in the development and evaluation of transportation policy and program options. It is prepared biennially by the FHWA and the Federal Transit Administration (FTA) for presentation to Congress. The report provides Congress and other decision makers with an appraisal of highway, bridge, and transit finance; physical conditions; operational performance; and future investment requirements. Future capital requirements are summarized as the cost to maintain conditions or the cost to improve conditions, among others. Capital requirements are estimated using TERM, HERS, and the Bridge Investment Analysis System (BIAS) to calculate the cost of preservation over a twenty-year period. The report also considers preservation versus expansion and enhancements.

The consultant team spoke with US DOT representatives about the Condition and Performance Report and identified several issues. First, conditions for one mode may affect another. The US DOT is currently looking at integrating or coordinating the HERS and TERM models. This issue is less likely to be a limitation for aviation. Second, asset models use different definitions for "maintaining conditions" or "improving conditions." For example, improving highway conditions is considered the "maximum economic investment," whereas improving bridge conditions is considered "eliminating deficiencies." Finally, the federal asset models rely on different databases from each other and utilize benefit-cost calculations differently.

Implementing an indicator for system preservation involves certain challenges. First, asset or program-specific performance measures (e.g., distressed lane miles of pavement) are widely used but are not comparable across modes. This requires an indicator that is able to evaluate the entire transportation system, such as the candidate indicators. Furthermore, it is difficult to construct a multi-modal measure at the systems level. The candidate indicators approach this issue by presenting condition in terms of the cost to preserve the system, thereby creating a comparable unit across modes.

Determining the condition of the system requires a great deal of analysis and engineering knowledge, yet preservation should be conveyed in a way that is understandable by non-technicians. As decision makers are presented annually with the cost to preserve the system, or an index that shows how the cost has changed, they

[1] US DOT, 1999 *Status of the Nation's Surface Transportation: Condition and Performance Report*

are able to develop an understanding of system preservation without needing a strong technical background. It is also challenging to communicate the importance of preservation activities to customers. For example, the benefits of maintenance activities may not be as readily apparent to customers as are the benefits of system expansion projects, and preservation efforts can be seen as "fixing something that isn't broken." As greater emphasis is placed on preservation efforts by decision makers, however, customers will begin to appreciate the benefits associated with preservation.

2.5 Infrastructure and Asset Management Systems

Identifying the system infrastructure or system assets is the first step to measuring asset condition and system preservation. The California transportation system consists of four major categories of assets:

- Highways
- Transit
- Rail
- Air.

Each of these asset categories can be further subdivided into smaller asset categories. For example, the Federal Highway Administration (FHWA) provides a standard classification for typical highway assets: infrastructure assets, including hardware, pavements, structures, and tunnels; and other assets, including construction and maintenance equipment, corporate data and information, human resources, materials, real estate, and vehicles. Various other classification systems are available for each asset category. For example, Caltrans classifies highway assets by family type in the highway system inventory, such as Flexible Pavement Family, Drainage/Vegetation Family, and Bridge Family. Similar classification systems exist for aviation, transit, and rail modes.

The purpose of asset management systems is to track the condition of existing transportation infrastructure/assets and the cost of their maintenance or improvement. They can be used to collect, analyze, and prioritize data in terms of infrastructure condition and capital investment needs. Asset management systems are important for forecasting costs and infrastructure needs, as well as for anticipating the impact of travel demand/trends (including truck volumes) on system conditions. In addition, they identify when and where new and improved technologies or materials can be applied and their impact on future infrastructure needs. Many different asset management systems exist that track single asset categories or combinations of assets. This section briefly describes some of the existing asset management tools.

2.5.1 Highway Assets

A common type of asset management system is a pavement management system. Many states have unique pavement management systems. The Caltrans Pavement Management System (PMS) is the primary tool at Caltrans for describing State Highway pavement condition, identifying and prioritizing projects, and estimating fiscal resources required to repair the system. It uses a three-criteria approach for determining the pavement rehabilitation needs of its roadways: maintenance service level, distress level, and ride level. These criteria provide information on various aspects of pavement condition. Caltrans is currently developing the Advanced Pavement Management System, which is expected to replace the existing PMS in the next two to four years. It will prioritize projects using benefit/cost analysis rather than the previous three-criteria approach.

Another tool, the Highway Economic Requirements System (HERS), could also be used for analyzing highway assets. There is both a federal and state-level version of HERS. The Federal Highway Administration's HERS, a simulation model, relies on the Highway Performance Monitoring System (HPMS) for information on current conditions and anticipated future travel growth. HERS, using HPMS data, evaluates the condition of highway segments with information on pavements, geometry, traffic volumes, vehicle mix, and other characteristics. Based on section-specific traffic growth projections, HERS forecasts future conditions and performance. When deficiencies are identified, HERS employs incremental benefit/cost analysis to evaluate highway investment requirements based on three scenarios:

- **Maintain Conditions**, where investments are made to maintain conditions at the base year level. Under this scenario, existing and accruing deficiencies are selectively corrected so that overall condition in Year Twenty matches the condition in Year One. Operational performance may improve or decline depending on the implemented improvements

- **Maintain User Costs**, where investments are made only to maintain user costs at a base year level. It sets system condition and performance so that the cost of using the system per vehicle-mile is the same as in the original year. Investment at a lower rate (maintain conditions scenario) would result in increased user costs and would negatively impact the economy

- **Maximum Economic Investment**, where investment is optimized by correcting all highway deficiencies when economically justified and when the benefits exceed the cost of the improvement. Investment at this level would result in decreased direct user costs over the project life cycle.

Both the *Maintain User Costs* and the *Maximum Economic Investment* scenarios consider the impact of the system on users by minimizing the costs that highway users absorb in the form of vehicle operating costs, travel time, and crash costs. HERS considers reductions in direct user costs, agency costs, and societal costs as benefits. The model implements improvements with the highest B/C ratios first. HERS selects alternative improvement actions and evaluates their effects to determine which improvements have the most economic value. It selects the set of actions that meets the criteria and falls within specified funding constraints or that meet a specified goal.

The HERS State Version (HERS/ST) provides a modified version for analysis on a state-level. HERS/ST can handle highway systems with up to 150,000 sections. It has many capabilities, including the application of user-specified deficiency criteria to identify potential pavement, capacity, and alignment improvements for individual sections; the estimation of the cost of improvements; the estimation of the benefits of improvements; and the evaluation and prioritization of improvements using benefit/cost analysis. HERS/ST *does not* support the Maintain User Costs analysis capability of HERS, but will calculate economic efficiency.

2.5.2 Bridge Assets

Bridges and other structures, two subcategories of highway assets, are typically managed separately from pavement. Caltrans uses an integrated bridge management system for tracking and assessing the condition of bridge structures in California. Responding to state interest, the FHWA initiated research into the applicability of asset management systems to bridge management that ultimately led to the development of Pontis. Pontis is a PC-based software system that allocates resources for bridge improvement needs based upon current and future bridge characteristics.

As a basis for evaluating bridge investments, inspectors record the condition of each element of each bridge. Bridge elements are classified according to the percentage of each element found in a particular condition state. Condition states describe the type and severity of element deterioration in visual terms (e.g., no corrosion, paint distress, rust formation, etc.). Pontis relies on a Markovian deterioration model to predict future conditions.

Pontis uses two scenarios for evaluating bridge investments:

- **Cost-to-Maintain**, with the goal to maintain the current state of bridge deficiencies
- **Cost-to-Improve**, with the goal to eliminate all bridge deficiencies over the next 20 years.

Caltrans has incorporated Pontis into its bridge management system and now generally refers to that system as Pontis. Pontis contains detailed information and inspection data on bridges and uses a prioritization process for selecting bridge repair and rehabilitation projects. Pontis is used for the prioritization process. The complete bridge management system is not integrated with other management systems in Caltrans. Data relevant to other management systems, such as the PMS, must be extracted from the bridge management system rather than transferred through direct interface.

2.5.3 Other Highway Assets

The management systems discussed so far do not include assets related to the maintenance and operation of the highway system. These assets are included in the Maintenance Management System (MMS). Although not an asset management system, the MMS is discussed in the context of other highway assets. The MMS is composed of a group of interrelated management tools designed to provide a basis for planning, scheduling, operating, and controlling highway maintenance efforts. The system contains four basic components: inventory, level of service, maintenance activities, and information subsystem. The MMS keeps track of the quantity of physical infrastructure per postmile (signs, guardrails, lanes, etc.) but does not include an inventory of condition. Therefore, it cannot be used to measure asset condition. A new management system (described in the following paragraph) will provide condition information. The current MMS, in a separate inventory from the infrastructure inventory, presents expenditures for the previous year for each asset type. The MMS includes items contained in the PMS and Pontis, but tracks different elements (e.g., lane miles of a bridge rather than the bridge as a whole structure). Other items, such as lighting and barriers, among others, are unique to the MMS.

A new management system is currently in development and will be released over the next few years by Caltrans district, beginning with District 3. The new system will track individual assets with a unique ID that indicates each asset's location and will provide information related to each asset's history of damage, repair, and replacement. Items that were not previously included in the MMS will be included in the new system through an expansion of existing families. The MMS presents expenditures per year per district by aggregated asset type within each family. The new system will provide expenditures for each asset by its individual ID. The MMS does not project future expenditures because of the variability of accidents, weather, standard deterioration, among others. Projections for future expenditures could be based upon the previous year's expenditures. The yearly difference in total expenditures is five to ten percent. The previous year's expenditures could serve as a basis on which to estimate future years, using a five to ten percent increase as an approximation. Limitations in funding, however, may not provide an accurate picture of expenditure needs. Therefore, it may be useful to rely on established practices for determining funding needs.

Caltrans has established preventive maintenance cycles for almost all assets to assess damages and the need for repair/replacement. These cycles provide an estimate of the following year's likely maintenance expenditures. Internal experts also track the need for infrastructure maintenance and can provide insight into future expenditure needs.

2.5.4 Transit Assets

Transit agencies typically do not use asset management systems, relying instead on book value depreciation of assets. For example, the Metropolitan Transit Development Board (MTDB) in San Diego, uses book value depreciation, in addition to a bus capital replacement plan, a triennial maintenance audit, and an annual capital improvement program to manage transit assets. Book value depreciation has certain limitations. For example, asset value depreciates in a straight line; buses are frequently depreciated over 12 years, while transit agencies typically keep buses for 14 years; and depreciation is not tied to condition for each asset.

Caltrans does not track transit system conditions, but that gap may be filled by the Federal Transit Administration's Transit Economic Requirements Model (TERM). TERM provides the ability to evaluate capital infrastructure needs for transit and utilizes data from the National Transit Database. TERM evaluates the economic return on transit capital investments. It estimates total annual capital expenditures required to maintain or improve both the physical condition of transit infrastructure and the level of service transit provides.

Using a set of statistically estimated, transit asset decay relationships, TERM artificially simulates the "aging" process for each asset contained in the Nation's existing stock of capital assets over a twenty year period. Once an asset's condition has reached the user-input minimum acceptable value, the asset is replaced. The replacement cost is then added to an annual tally of investment needs.

The model prioritizes transit preservation investments using benefit/cost ratios. TERM currently considers three types of benefits for evaluating investments:

- **Transportation system user benefits**, including travel time savings, reduced highway congestion and delay, reduced auto costs, and improved mobility

- **Transit agency benefits**, including fare revenue increases, and reductions in operating and maintenance costs

- **Societal benefits**, including reductions in air and noise emissions, roadway wear, and transportation system administration.

2.5.5 Aviation Assets

Airfield pavement is a major component of the aviation system. Caltrans uses an Airport Pavement Management System (APMS) to track the condition of airfield pavement. Caltrans initiated the APMS in 1987-88 with funding from the FAA. The current APMS includes data on 164 general aviation and smaller commercial airports (out of 266 total airports statewide) from 1994-95; a new system in development will include 200 airports. Neither the existing nor future APMS will include the largest commercial airports, but will include smaller hubs (Fresno, Stockton, Bakersfield, etc.). The current and future APMS will not include any other assets beyond airfield pavement. The APMS provides airport owners with current and projected needs for repairing, maintaining, or preserving airfield pavements, including the associated costs. It also provides the State and FAA with a list of current and projected preservation needs for the statewide airport system

Pavement condition in the APMS is assessed using MicroPAVER, a PC-based asset management system that can assess the relative condition of airfield pavements. The U.S. Army Construction Engineering Research Laboratories (CERL) developed the MicroPAVER Pavement Management System with FAA and FHWA assistance. In the APMS, data is obtained for each airport by an on-site review team who perform a visual pavement condition survey using standard guidelines established by FAA Advisory Circular 150/5380-06, *Guidelines and Procedures for Maintenance of Airport Pavements*. Observations of pavement distress type, extent, and severity are input into MicroPAVER for calculation of the Pavement Condition Index (PCI). For each airport, an AutoCAD map of the airport is produced that graphically displays sections of the pavement. The AMPS generates estimated costs for current repair needs, as well as five year investment requirements if the repairs are deferred.

Condition on other airport assets beyond pavement is not readily available. No method currently exists for determining the condition of the terminal. Equipment is either owned privately by the airlines or by the airport. Airlines and airports may track condition in order to time replacement decisions, however they do not necessarily have the capacity to analyze different investment scenarios. Obtaining data on other assets would likely require Caltrans to conduct a semi-annual survey, in addition, airlines and airports have little incentive to provide asset information to Caltrans.

2.5.6 Rail Assets

A similar system to MicroPAVER has been developed for evaluating railroad track conditions, and planning maintenance and repair. CERL developed a companion system to MicroPAVER for rail track called RAILER. RAILER is capable of track management on military, short line, and industrial track networks. Established track standards and CERL-developed condition indexes enable RAILER to evaluate track conditions and determine deterioration rates. RAILER has several capabilities,

including track inventory, track and safety inspection, condition assessment, maintenance and repair (M&R), budget planning, and GIS capabilities.

RAILER uses condition indexes, track standards, and the Army's Installation Status Report (ISR) for condition assessment. The indexes measure track segment and component health on a scale of 0-100. The indexes indicate the required maintenance actions to restore or sustain acceptable track condition. They are also used to determine track deterioration rates and to provide input to the Army ISR. Track standards match operating restrictions to specific track defects.

2.6 Other Considerations: Defining Performance and the System

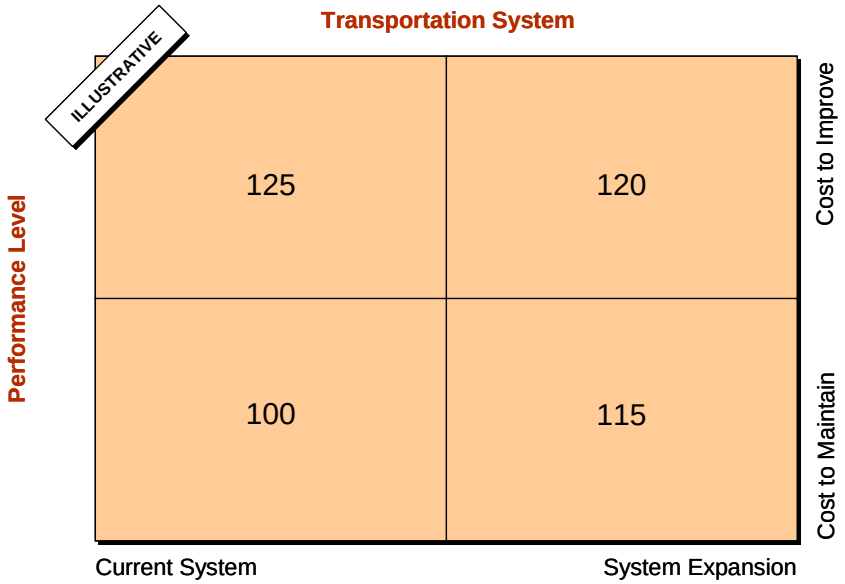
As discussed in the Section 2.2, Asset Condition is the appropriate indicator to evaluate preservation of California's major transportation assets. In order to measure asset condition from a preservation perspective, however, the indicator must satisfy certain requirements.

The candidate preservation indicator and supplemental system techniques should:

- Evaluate and monitor condition for the chosen asset, mode, or the entire system
- Evaluate and monitor condition to a predetermined performance level
- Consider potential performance levels, as well as the definition of the asset, mode, or system.

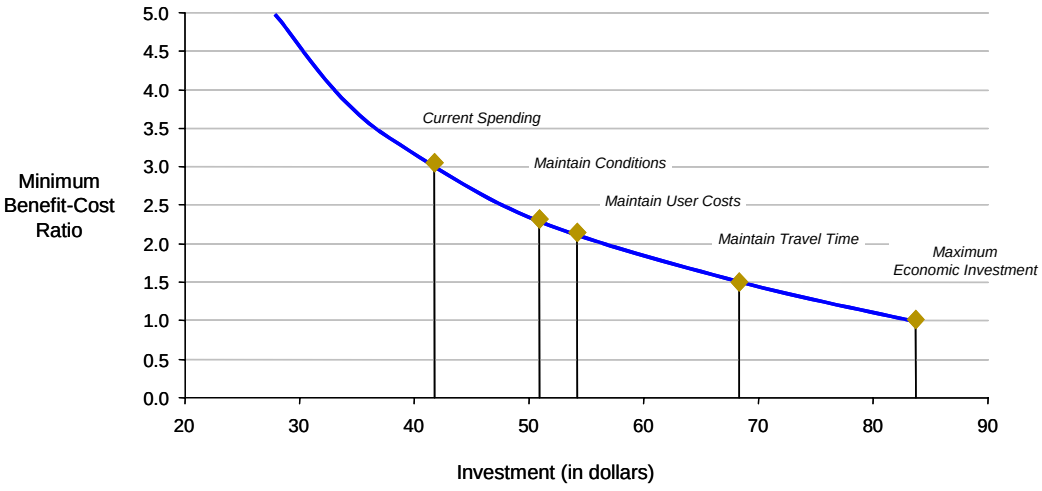
Evaluating condition, whether for an individual asset or for the entire system, encompasses both a range of performance levels and the magnitude of the "system" (i.e., the entire transportation system or a subset of the system, such as a particular mode or asset). This concept can be illustrated in a matrix, which provides a choice of performance levels between the "cost to maintain" conditions and the "cost to improve" conditions. Also, the matrix presents two choices for the definition of the system: the current system or the current system plus planned expansions. In other words, if the current system is chosen as the focus, then performance can be evaluated as the "cost to maintain" the current system or the "cost to improve" the current system. For example, as illustrated in Exhibit 8, the cost to maintain the current system is less costly (100) than the cost to improve the system (125), because the cost to maintain scenario only attempts to maintain the system's condition in Year One over a twenty-year period and does not attempt to correct all system deficiencies.

Exhibit 8: Performance and System Magnitude



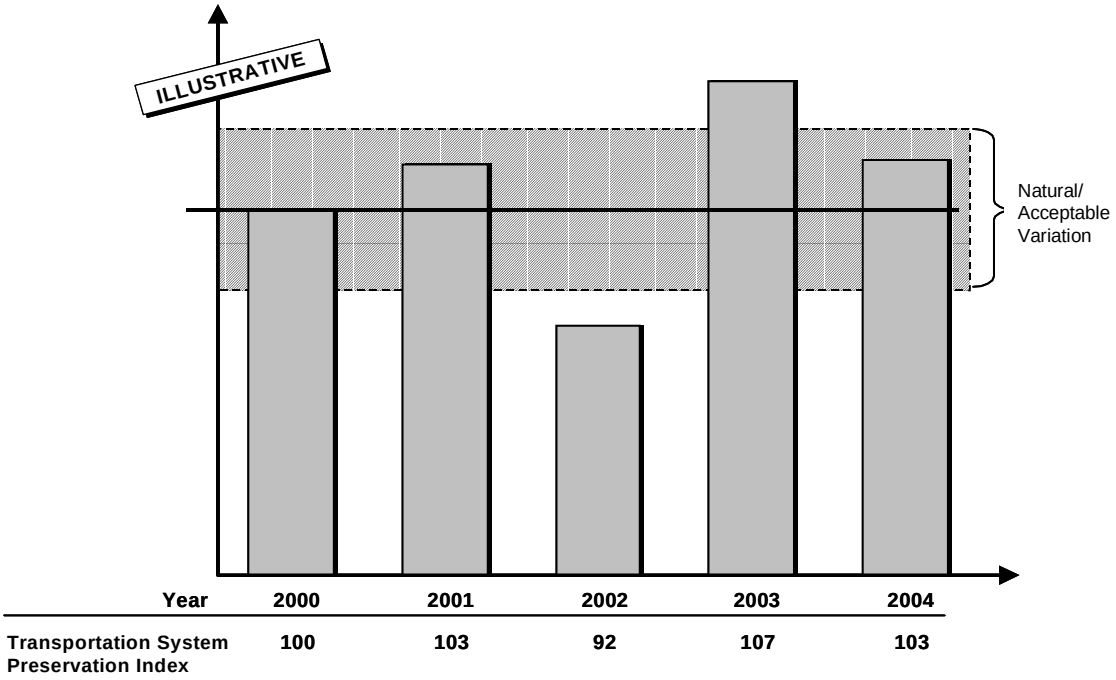
Performance can be defined in several ways. For example, it can be defined by level of repair (i.e., asset condition), user costs, or cost effective investments. Different performance thresholds include the cost to maintain conditions, the cost to improve conditions, the cost to maintain user costs, and the cost to maintain travel time. Exhibit 9 illustrates potential performance levels, and how the investment required increases (relative to the benefit-cost ratio) depending on the desired performance level. Although the SMWG recognized that several performance definitions would be useful, the groups recommended focusing on current conditions, at least in the near term.

Exhibit 9: Comparison of Performance Levels



Several factors related to the performance level need to be considered when evaluating preservation. Today's infrastructure condition is not necessarily the appropriate maintenance level. As described in Section 2.5 and presented in Exhibit 9, asset management systems provide several alternative performance levels, including maintaining conditions, improving conditions, or maintaining user costs. Several performance levels are also in use at Caltrans. For example, the 2000 State Highway Operation and Protection Program (SHOPP) Plan sets a goal of 7,400 lane-miles of distressed pavement at the end of the four-year funding period. If "maintaining conditions" is selected as the appropriate performance level, conditions may decrease over time. This occurs when a lower target is established and reinforced as each year only maintains the condition of the previous year. An established target, such as the cost to maintain conditions in the first year, will ensure that conditions are not allowed to decline. Another issue to consider is that a *natural variation* in the measure is likely to result due to varying conditions and replacement needs. The level of natural, acceptable variation needs to be established. This variation is presented in Exhibit 10.

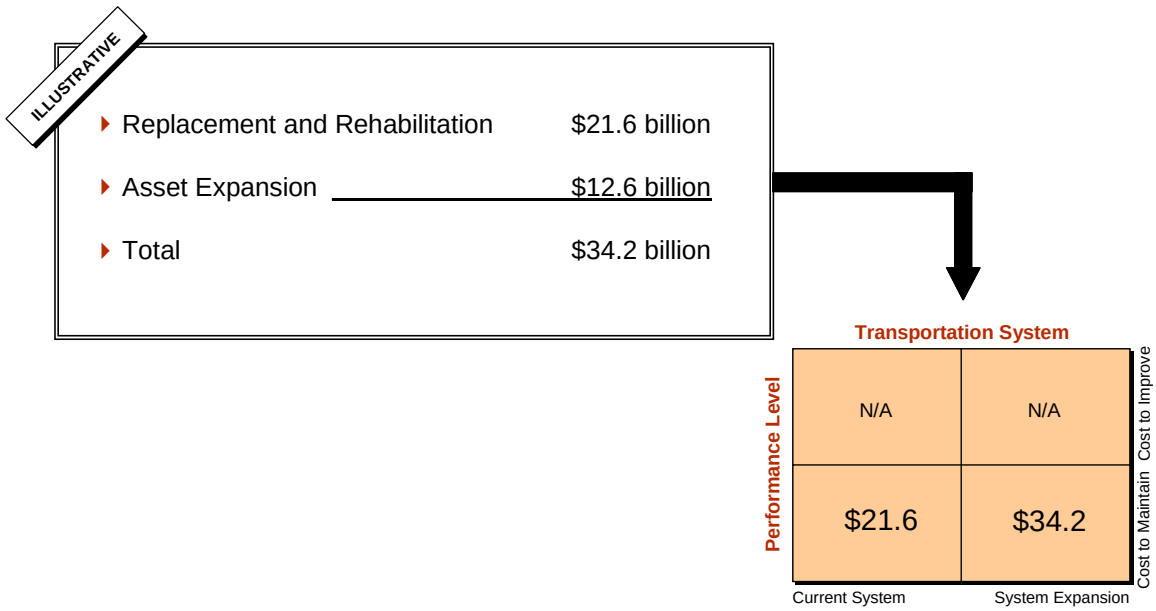
Exhibit 10: Natural Acceptable Variation in Condition



The system can also be defined in several ways for each asset. For bridges and highways, "system preservation" includes the investment required to preserve and maintain infrastructure (including resurfacing, rehabilitation, and reconstruction). "System expansion" includes costs related to adding lanes to existing facilities or adding new roads and bridges. Finally, "system enhancements" includes all safety enhancements, traffic operations improvements, and environmental improvements. Similar definitions exist for transit, including "replacement and rehabilitation," "asset expansion," and "performance improvements." The first two definitions in each case

are probably appropriate for a transportation system preservation indicator. Exhibit 11 illustrates the cost to maintain conditions for the "replacement and rehabilitation" and "asset expansion" for transit.

Exhibit 11: 20-Year Transit Needs in California Example



Source: TERM model (FTA), Booz Allen Analysis, Data for 1998-2017

Exhibit 11 illustrates the different costs associated with the cost to maintain the current system and the expanded system for California transit assets from 1998 to 2017. If the condition of the current system were maintained over the twenty year period, it would cost $21.6 billion. However, if the expanded system were maintained over this same period, it would cost $34.2, a difference of $12.2 billion. Therefore, it is important to develop an understanding of the "system" that is to be preserved.

2.7 Opportunities for Usage

The Transportation System Preservation outcome provides several opportunities for decision makers. The condition of the system can be monitored and reported, which suggests a focus on current conditions. Condition can be presented by critical asset or mode. Additionally, the Preservation Index can present the condition of the entire system and show how it has changed over time. Showing the condition of the system over time can help to justify the importance of maintenance activities. It can also allow engineers and decision makers to consider the impact of wide-reaching program strategies (e.g., long-life pavement). Furthermore, knowledge of the condition of the system will help decision makers determine the appropriate allocation between maintenance and expansion activities.

The outcome can also help to provide state-level strategic direction for the California Transportation Plan (CTP) and California Aviation System Plan (CASP). Finally, an understanding of condition will help address the accounting mandate under the Governmental Accounting Standards Board (GASB) Statement No. 34, which requires state and local governments to report the value of infrastructure assets.

The preservation outcome will also be useful to regional agencies. It can add quantitative measurement to the goals outlined in Regional Transportation Plans (RTPs) and strategic planning documents. For example, the Shasta County Regional Transportation Planning Agency's RTP goals and policies include several statements that emphasize preservation, such as:

- *Developing plans and programs which emphasize reconstruction and improvement projects on existing roads that will enhance safety, circulation and traffic flow*

- *Providing adequate funding to maintain the existing transit fleet and for fleet expansion as necessary.*

The preservation outcome could provide a basis by which to demonstrate a need for greater maintenance funding for the region. Finally, it could also address concerns of consumer advocacy groups that system expansion projects are given greater priority over maintenance and operations (e.g., expanding a subway rather than operating an existing bus system).

3. WHERE ARE WE HEADED NOW?

3.1 Recommendations

The Transportation System Preservation outcome faces many opportunities. Preservation is already being measured at Caltrans for many assets. For example, the Bridge Health Index provides an assessment of bridges and distressed lane miles indicate the condition of pavement. Additionally, many management systems are already in use at Caltrans and other agencies, including the Pavement Management System, Airport Pavement Management System, and Pontis. Other asset management systems are available and could be used to measure condition, such as HERS, TERM, and RAILER.

The California Transportation Commission (CTC) and state-level decision makers already incorporate preservation into policy decisions when they allocate funding between the STIP and SHOPP. The preservation outcome could also help to address the accounting mandate under GASB 34, which requires states and local governments to begin reporting the value of infrastructure assets.

Based on the fact that preservation is already incorporated into policy decisions and that there are several opportunities for further usage, it is recommended that system preservation be presented in a status and trend report. Initially, Asset Condition could be presented for major asset categories. Later, the Cost to Achieve a Desired Condition or the Preservation Index could be added. The indicators would provide decision makers with an understanding of the dollars required to preserve the system, as well as the change in cost from the previous year(s). Over time, this will provide significant insight to decision makers as to how well the system is being preserved and if additional resources should be devoted to preservation activities.

3.2 Next Steps

Adopt the asset condition indicator now for evaluating individual assets. Several decisions need to be made for possible adoption of the candidate system indicators. Two candidate indicators, Cost to Achieve Desired Condition and the Preservation Index, require additional proof-of-concept testing to determine the appropriateness of adopting them. In order to establish consistency in calculating the candidate indicators, a condition/performance level is needed. The SMWG recommended focusing on the level of repair (i.e., asset condition) instead of user costs or cost effectiveness. Further proof-of-concept testing should provide direction as to the appropriate level. Maintaining existing asset conditions may be the optimal choice for performance level because improving conditions to other thresholds begins to overlap with other performance outcomes.

The SMWG also recommended exploring both the current system and planned expansions as potential system definitions. For example, understanding the condition of the current system would be useful for reporting the State of the System, while planned expansions could assist with planning purposes. Finally, it is recommended that operating costs be excluded from the calculation of the preservation outcome, based on the capabilities of the asset management systems and the availability of operating cost data.